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Spruce budworm - Newfoundland

1979
ENVIRONMENTAL MONITORING
OF THE
SPRUCE BUDWORM SPRAY PROGRAM
IN
NEWFOUNDLAND

FINAL REPORT

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INTRODUCTION

Background

During the 1978 spraying program against the spruce budworm in Newfoundland, in which 376,000 ha of forest were sprayed with Matacil, an environmental monitoring program was carried out under the administration of Dept. of Consumer Affairs & Environment. This program dealt chiefly with populations of non-target aquatic and terrestrial organisms, the persistence of Matacil residues in the environment and measurement of spray deposit. In 1979 there was no chemical insecticide spraying in the province. Instead, the Dept. of Forest Resources & Lands carried out a limited operational protection program using the bacterial control agent Bacillus thuringiensis (B.t.) over approx. 6000 ha in central and south-central Newfoundland.

The aims of the environmental monitoring program for 1979 were: (a) to assess the residual effects of the 1978 Matacil spraying on populations of non-target organisms after one year; (b) to assess short-term impacts of the 1979 B.t. spraying on non-target populations. In addition, measurements of Matacil residues (one and two years post-spray) in areas sprayed in 1977 and 1978, and viable spore counts in soil samples taken from areas sprayed with B.t. were made.

Because spray blocks are bounded by no physical borders, there are limitations on any relatively long-term program that monitors population densities of dispersable non-target populations in sprayed areas. Even if there were a long-term impact on a population of a given animal species due to spraying, such impact might be reflected in a decline in population density (i.e. mortality) in spray areas in the short-term, but in time, the "vacuum" in population density might well be replaced by individuals dispersing into the sprayed area from unsprayed territory. The rate at which the vacuum is filled would depend upon the tendency of the species to disperse. Thus, in general terms, the minimum acceptable size of a sprayed monitoring block increases as (a) the longitudinal scope of the monitoring program (i.e. from short-, to longer-term), and (b) the tendency to disperse of the non-target species under consideration. For this reason, programs that were carried out as short-term studies in 1978 with such highly dispersable groups as shrews, aquatic insects and flying insects were not repeated as long-term studies in 1979.

Included in the Matacil study were programs dealing with birds (most of the species under study are territorial, and hence little net dispersal can be assumed throughout the study season) and terrestrial arthropods with relatively low dispersal tendencies such as "resident" plant-dwelling and soil-dwelling types.

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For logistical reasons the spray blocks selected for operational spraying with B.t. in 1979 were far smaller than the blocks used for Matacil spraying in 1978. Hence, studies dealing with relatively dispersable populations could not be carried out even on a short-term basis; also, the blocks were too small to carry out the bird program. Hence, only studies of "resident" arthropods were carried out.

The B.t. environmental monitoring program should be viewed, at present, as a short-term (i.e. one-season) evaluation. The Matacil monitoring study represents a step along the path towards a long-term assessment of environmental impact, as recommended in the 1978 environmental monitoring report. It should be remembered that the latter program assesses the residual effects of a single spray-year, to be distinguished from the effects, after one year, of a yearly spray program.

Study sites

All of the test (sprayed) and control (unsprayed) study sites were located in the Gander-Grand Falls area. The sites used for studies on birds and terrestrial arthropods are listed in Table 1 and the locations shown in Figure 1. Test sites are designated in an X-series and control sites in a C-series. Matacil residue samples were taken from sites listed in Table 2.

In addition to those in areas of mature forest, sites were chosen also in regeneration forest areas (ca. 15-20 yrs. growth of fir and spruce), since regeneration stands constitute much of the high-risk budworm infestation area. Test and control sites were chosen in groups such that: (a) insofar as possible, the forest type and vegetation species mix were similar among members of the group (b) the test site(s) of the group lay well inside a spray block, the control sites well outside of any spray block. In this way, comparisons of population densities of non-target organisms could be made among sites that were approximately similar apart from spraying history.

Staff

The field work was done by five university students who were graduates or undergraduates in biology. Laboratory work, involving sorting and identification of terrestrial and soil-dwelling arthropods was carried out by six university students of biology.

Spray Regimes

The Matacil spray regimes for 1978 are given in D.C.A.E. report No. RA-79-2.

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TABLE 1 Sampling sites for studies of populations of non-target organisms (see Figure 1)

Site	Spray history	Forest Type[1,2]	Programs
Group I (mature forest):			
C1	not sprayed	BF/S/M (mature)	terr. arthr., soil arthr.
C5	not sprayed	BF/S/M (mature)	soil arthr.
X1	Matacil 1978	BF/S/M (mature)	terr. arthr., soil arthr.
C4	not sprayed	BF/S/M (mature)	birds
X4	Matacil 1978	BF/S/M (mature)	birds, soil arthr.
Group II (regeneration)			
C2	not sprayed	S/Br/As/Al/BF/K (2m)	terr. arthr.
C3	not sprayed	Br/Al/K/BF/S (2m)	terr. arthr., soil arthr.
X2	Matacil 1978	Br/BF/S/As/Al/K (2m)	terr. arthr.
X3	Matacil 1978	BF/Br/S/Al/As/K (2m)	terr. arthr., soil arthr., birds
B	B.t. 1979	BF/Br/S/Al/As/K (2m)	terr. arthr.

Legend: Al alder, As aspen, BF balsam fir, Br white birch, K kalmia, M moss substrate, S spruce.

1 Vegetation types listed in descending order of dominance, as determined subjectively.

2 Approximate height of stand appears in parentheses.

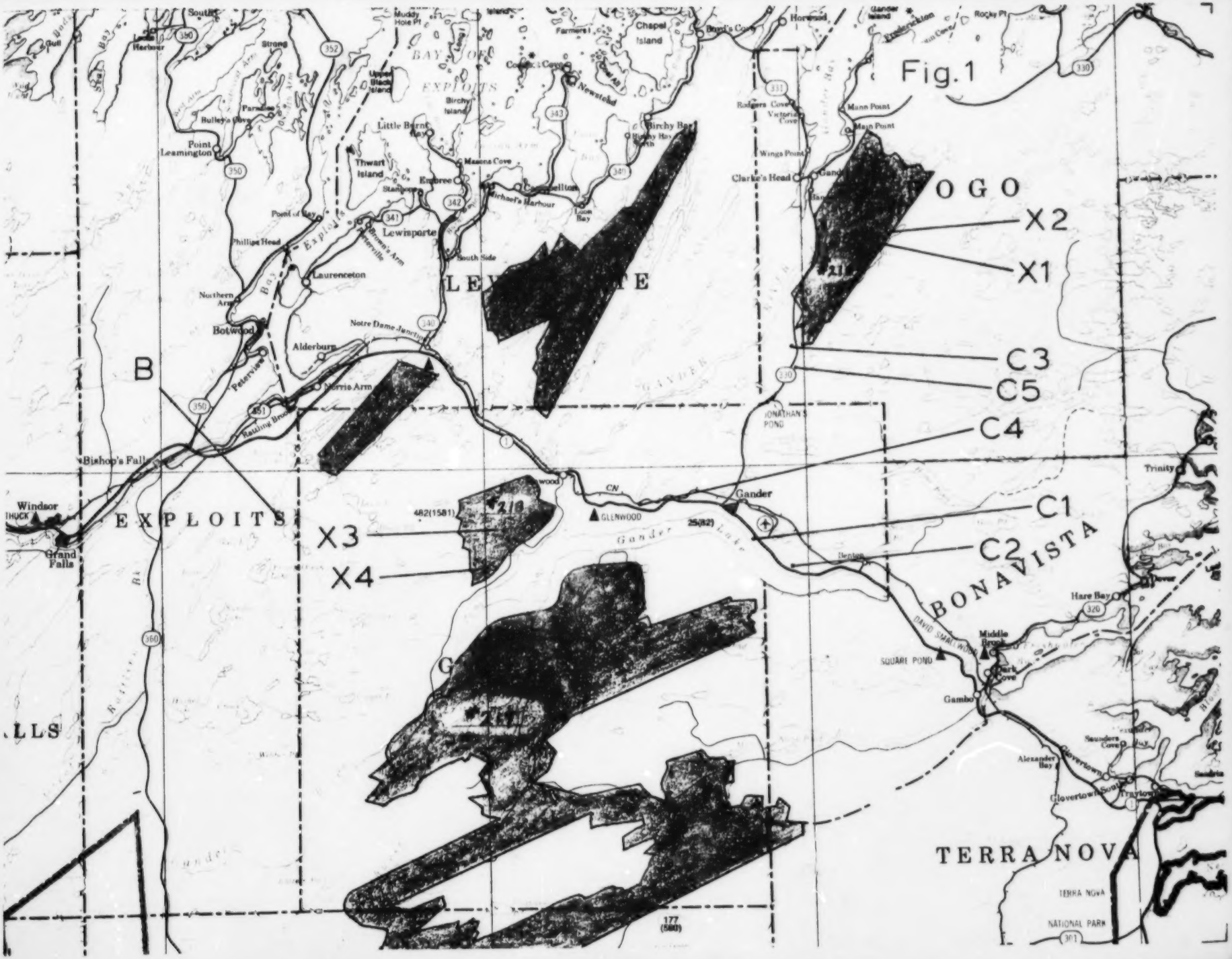
Fig.1
OGO
X2
X1
C3
C5
C4
C1
C2
X3
X4
B
EXPLOITS
BONAVISTA
TERRA NOVA
Lewisporte
Botwood
Bishop's Falls
Windsor
Grand Falls
Gander
Glenwood
Laurenceton
Alderbury
Norris Arm
Point Leamington
Hare Bay
Gambo
Trinity
Clarke's Head
Mann Point
Main Point
Birchy Bay
Newstead
Chapel Island
Horwood
Jonathan's Pond
Square Pond
Middle Brook
Terra Nova National Park

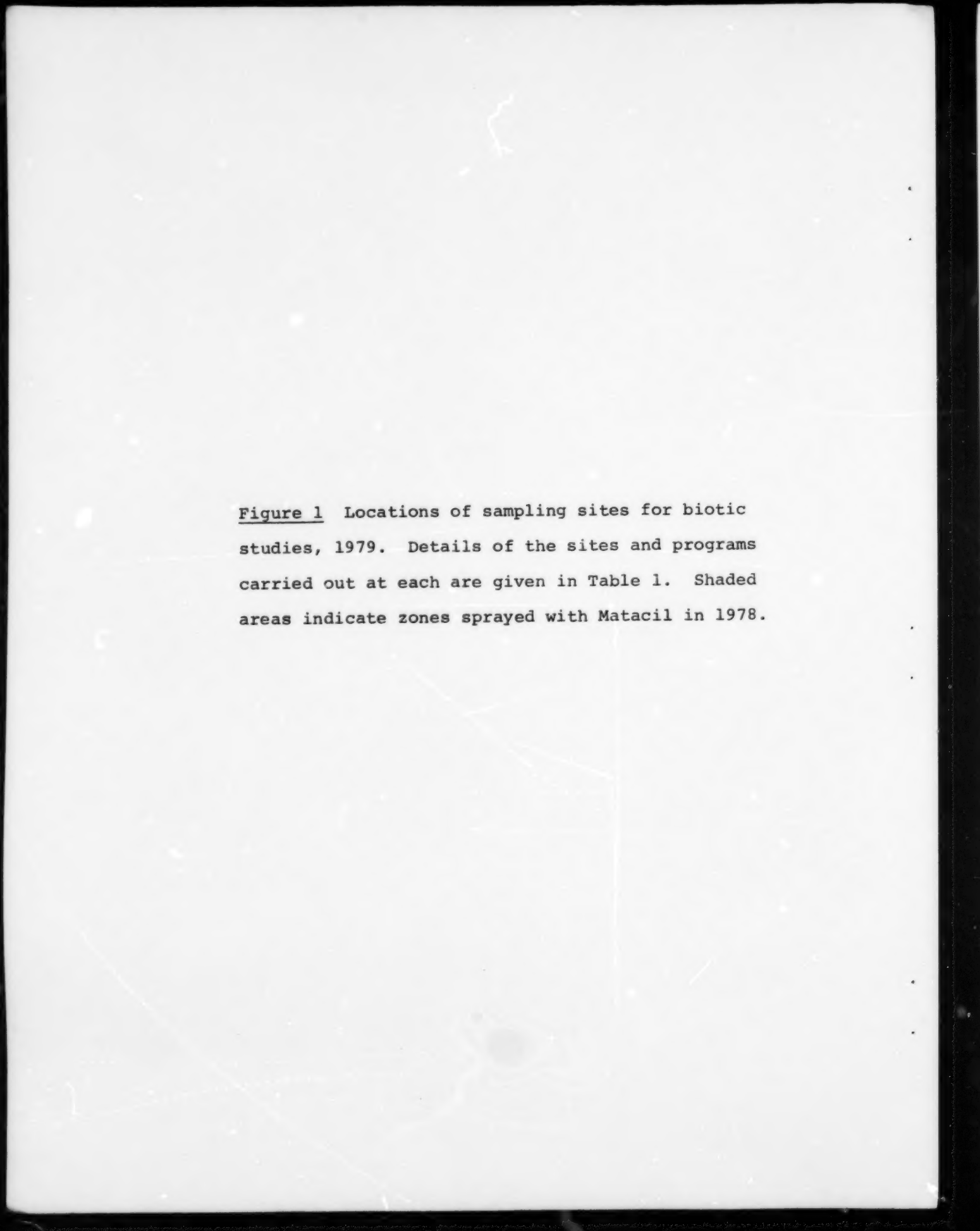

Figure 1 Locations of sampling sites for biotic studies, 1979. Details of the sites and programs carried out at each are given in Table 1. Shaded areas indicate zones sprayed with Matacil in 1978.

Table 2 Sites used in sampling for insecticide residues in vegetation and soil

Site No.[1]	Spray history, date	Forest type[2]	Collections[2]	Collection date
A1	not sprayed	R	F, V, S	79-07-04
A2	not sprayed	R	F, V, S	79-07-04
A3	not sprayed	MF	F, S	79-07-04
W1	Matacil (2x70 g/ha), 78-06-19,25	MF	S	79-05-30
W2		R	F, V, S	79-05-30
W3		MF	S	79-05-30
W4		R	F, V, S	79-05-30
G1	Matacil (2x70 g/ha), 78-06-18, 26	R	F, V, S	79-05-30
G2		MF	V, S	79-05-30
G3		R	F, V, S	79-05-30
G4		MF	V, S	79-05-30
P1	Matacil (3x70 g/ha), 77-06-17, 23 & 77-07-01	R	F	79-09-07
P2		R	F	79-09-07
P3		R	F	79-09-07
H1	Fenitrothion (2x210 g/ha), 77-06-19,25	R	F	79-09-06
H2		R	F	79-09-06
M1	Matacil (2x70 g/ha), 78-06-18, 26	-	Pond sediment	79-08-22

1. Site Locations: A1, A2, A3: Terra Nova National Park.
P1, P2, P3: Pinchgut Lake, near Corner Brook.
H1, H2 : Gales Brook, near Hampden.
W, Weirs Pd., north of Gander;
G, Glenwood vicinity;
M, Careless Pd., Glenwood area.

2. Legend: MF mature balsam fir/spruce forest, R regeneration stand.
F balsam fir needles, V ground vegetation, S soil.

In June 1979, approximately 6000 ha. of forest were sprayed with B.t.: 3600 ha. in the Central Region and 2400 ha. in the Bay d'Espoir area.

At Jumper's Brook, which was the area selected for environmental monitoring for B.t., 800 ha. were sprayed with B.t. at a nominal dosage rate of 20 BIU/ha. (8 BIU/ac.). The spraying was carried out once (on June 17, a.m.) using four Cessna AG Trucks flying at an altitude of approx. 15 m producing a swath width of approx. 30 m. The block was sprayed in sections since the capacity of this type of aircraft enables it to treat a maximum of 80 ha per load.

BIRD POPULATIONS

MATERIALS AND METHODS

The longer term impact of Matacil (aminocarb) spraying on bird populations was monitored in the Gander area. Studies were conducted at (1) Joe Batt's Pond (unsprayed; monitored in 1978) 11 km west of Gander, (2) Big Careless Cove Brook (sprayed and monitored in 1978) approximately 16 km SW of Glenwood, and (3) Little Careless Cove Brook (sprayed in 1978). Since the Big Careless Cove Brook area is at the fringe of block #218 the possibility exists that spraying of this area in 1978 may have been relatively light. The Little Careless Cove Brook area which is in the centre of block #218 and would presumably be more likely to have been uniformly sprayed during 1978 was therefore chosen as an additional area to be studied in 1979.

Ten Japanese mist nets were set in each of the spray areas and in the control area. Nets were 9 m or 12 m in length and 2 m in width, and were set on 3 m aluminum poles. Nets were positioned across probable bird flight paths, set as inconspicuously as possible, with the bottom panel of the net touching the ground or the top of the understorey. Nets were set at a minimum of 200 m apart. In the control area, netting was carried out twice a week, weather permitting. In the sprayed areas, once the immature birds had been fledged, netting was carried out once per week in each area, weather permitting, for logistical reasons.

Mist netting studies were conducted during the period 28 May to 18 August. The temperature, cloud cover, precipitation, relative humidity, light intensity and wind velocity were recorded for each day that netting was carried out. Mist netting was not attempted when high winds or rain prevailed.

To quantify differences and/or habitat similarities among the three areas, structural features of the vegetation were measured at all mist net sites, based on a method described by James (1971)

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and James and Shugart (1970) with several modifications deemed better suited to the present study as suggested in Hudson (1978).

RESULTS

The collection data are summarized in Tables 3 and 4.

Evaluation of the data indicates:

(1) Twenty-seven species of birds were captured in the control area, 28 species at Big Careless Cove Brook and 32 species at Little Careless Cove Brook. Captures of the 19 species common to all 3 areas accounted for 93.7% of total captures in the control area, 96.1% at Big Careless Cove Brook and 95.2% at Little Careless Cove Brook.

(2) Of the 19 species of birds common to all areas, 10 species- viz., Yellow-rumped Warbler, Northern Waterthrush, Black-and-white Warbler, Blackpoll Warbler, White-throated Sparrow, Lincoln's Sparrow, Ruby-crowned Kinglet, Yellow-bellied Flycatcher, Swainson's Thrush and American Robins- can be considered as indicator species on the basis of their frequency of occurrence. These 10 species account for 85.3% of the individual birds in the control area, 83.3% at Big Careless Cove Brook and 79.7% at Little Careless Cove Brook.

(3) The number of purely insectivorous individuals netted at the control area represented 67.4% of the total (1978 - 63.8%), at Big Careless Cove Brook 48.7% of the total (1978 - 54.2%) and at Little Careless Cove Brook 44.2% of the total.

(4) A total of 627 individual birds of the year (i.e. birds hatched in 1979) were netted in the control area for a ratio of 1 adult: 2.58 immatures (1978 ratio - 1 adult: 2.2 immatures). At Big Careless Cove Brook, 233 individual immatures were netted for a ratio of 1 adult: 1 immature (1978 ratio - 1 adult: 0.93 immatures). At Little Careless Cove Brook 564 immatures were netted for a ratio of 1 adult: 1.76 immatures.

(5) A "return" is defined as a banded bird recaptured within the same 10' grid of latitude and longitude in which it was originally banded and at least 90 days from the date of banding. Of the 326 individuals banded in the control area in 1978, 12 were recaptured in 1979, a return rate of 3.68%. At Big Careless Cove Brook 247 individuals were banded in 1978 and of these, 30 were recaptured in the same area in 1979, a return rate of 12.15%. Return rates were also calculated including only those birds banded in 1978 as adults. At the control area 132 adults were banded in 1978 and of these, 12 were recaptured in 1979, a return rate of 9.09%. At Big Careless Cove Brook 168 adults were banded in 1978 and of these, 28 were recaptured in 1979, a return rate of 16.67%.

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(6) A "repeat" is defined as a banded bird captured within the same 10' grid of latitude and longitude within the same 3-month period in which it was originally banded or recaptured. Of the total captures in the control area 8.9% were repeats (1978 - 12.8%); at Big Careless Cove Brook 10.2% were repeats (1978 - 13.7%) and at Little Careless Cove Brook 6.26%.

(7) The success of the mist net procedures as measured by number of birds captured per net-hour is as follows:

Weeks

	1	2	3	4	5	6	7	8	9	10	11	12
Control	2.97	3.55	3.91	3.38	3,50	3.20	6.07	13.14	20.87	30.52	21.0	21.6
Big C.C.B.	4.20	2,78	4.89		3,13	4,39	8.37	8.61	9.79	12.00	36.0	
Little C.C.B.		9.22	5.40	5.20	5.50	6.95	8.88	10.15	11.18	34.60	37.0	26.6

The increase in net success in the later weeks of the study is attributed to the addition of the birds of the year to the community.

(8) Measurements of structural features of the vegetation e.g. tree species, diameter, canopy height and cover, were subjected to a principal components analysis to simplify and condense the data so as to bring out relationships among and between the measured variables (Pielou, 1977). This analysis reduced the 22 variables measured in 8 principal components which accounted for 79.2% of the variation. There was no significant difference between the control area and Big Careless Cove Brook for any of the 8 principal components. The control area and Little Careless Cove Brook, however, were shown to be significantly different for Principal Component I - the presence of Pin Cherry, White Birch and Willow species, the control area lacking this component.

The percentage variation of bird species distribution attributable to the vegetation differences between net sites as represented by the principal components was determined through step-wise multiple regression analyses. A significant choice was shown by Swainson's Thrushes, American Robins and Hermit Thrushes for Principal Component I. These species comprised 10.23% of the total individuals in the control area, 13.95% at Big Careless Cove Brook and 29.22% at Little Careless Cove Brook. The considerably higher percentage at Little Careless Cove can be attributed to this component.

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TABLE 3. The numbers of birds recovered in mist-nets in 1979 from a control site (unsprayed) and from 2 test sites (sprayed in 1978 with Matacil). See table 4 for legend of bird species names. AHY-U = adult, sex unknown; HY = hatched in 1979.

Bird Species	Joe Batt's Pd. (Control) ♂	♀	AHY-U	HY	Total	Big Careless Cv. Bk. (Test) ♂	♀	AHY-U	HY	Total	Little Careless Cv. Bk. (Test) ♂	♀	AHY-U	HY	Total
YR	18	7		212	237	8	5		48	61	4	5		48	57
NWT	8	10	13	84	115	9	5	16	20	50	16	6	14	60	96
BW	11	8	1	25	45	12	8		3	23	12	17		6	35
WIL	6			4	10	6	3		0	9	15	4	2	3	24
BP	2	1		27	30	13	4		16	33	13	8		39	60
PALM				0	0	1			10	11				9	9
OV	3	3	2	8	16				0	0			1	1	2
MA	6			5	11	7	1		5	13	8	1		9	18
MO	7	1	1	8	17	3	1		0	4	6	3		12	21
RST	4	1		13	18				0	0				5	5
TENN	1	3		0	4	1	1		1	3		1		4	5
BEN	1	1		3	5				0	0				0	0
YW		1		0	1	1			0	1	1	1		1	3
Bay-Br				0	0		1		0	1				0	0
NASH				0	0		1		0	1				0	0
WTS	16	12	8	60	96	14	10	9	60	93	16	10	15	77	118
LIS	7	7	7	43	64	1	7	17	19	44	2	9	13	34	[illegible]
FOX	1	2		5	8	3	4	1	3	11	3	12	3	3	[illegible]
PIG				0	0	1	1		0	2		4		0	[illegible]
PF	2	3		0	5	1			4	5	2	1		5	8
SWS	1			1	2				0	0				1	1
J				0	0				1	1				1	1
PS				0	0				0	0				1	1
GT			1	3	4				0	0			2	0	2
RCK	2	3	1	38	44		1		5	6	1			28	29
GCK	1	1		2	4				0	0				0	0
YBF			12	18	30			17	5	22		3	21	14	38
F	1			0	1				0	0	2			0	2
DOW				0	0			1	0	1	1	2		0	3
HW				0	0				0	0		1		0	1
BOC			6	3	9			3	0	3				0	0
BCC	1		3	1	5		1	1	0	2			1	0	1
TS				0	0				0	0			2	0	2
SPH				0	0		1		0	1				0	0
ST	5	3	7	45	60	4	1	14	24	43	17	7	17	142	183
R	6	3		12	21	8	1	1	3	13	3	4		23	30
HT			1	7	8			2	6	8	1	2	3	36	42
GCT				0	0			1	0	1			1	2	3
Totals:	110	70	63	627	870	93	57	83	233	466	123	101	95	564	883

TABLE 4. List of bird species recovered in the 1979 mist-netting program.

YR	Yellow-rumped Warbler	Dendroica coronata
NWT	Northern Waterthrush	Seiurus noveboracensis
BW	Black-and-white Warbler	Mniotilta varia
WIL	Wilson's Warbler	Wilsonia pusilla
BP	Blackpoll Warbler	Dendroica striata
PALM	Palm Warbler	Dendroica palmarum
OV	Ovenbird	Seiurus aurocapillus
MA	Magnolia Warbler	Dendroica magnolia
MO	Mourning Warbler	Oporornis philadelphia
RST	American Redstart	Setophaga ruticilla
TENN	Tennessee Warbler	Vermivora peregrina
BEN	Black-throated Green Warbler	Dendroica virens
YW	Yellow Warbler	Dendroica petechia
Bay-Br	Bay-breasted Warbler	Dendroica castanea
NASH	Nashville Warbler	Vermivora ruficapilla
WTS	White-throated Sparrow	Zonotrichia albicollis
LIS	Lincoln's Sparrow	Melospiza lincolnii
FOX	Fox Sparrow	Passerella iliaca
PIG	Pine Grosbeak	Pinicola enucleator
PF	Purple Finch	Carpodacus purpureus
SWS	Swamp Sparrow	Melospiza georgiana
J	Slate-coloured Junco	Junco hyemalis
PS	Pine Siskin	Carduelis pinus
GJ	Grey Jay	Perisoreus canadensis
RCK	Ruby-crowned kinglet	Regulus calendula
GCK	Golden-crowned Kinglet	Regulus satrapa
YBF	Yellow-bellied Flycatcher	Empidonax flaviventris
F	Golden-shafted Flicker	Colaptes auratus
DOW	Douny Woodpecker	Picoides velosus
HW	Hairy Woodpecker	Picoides pubescens
BOC	Boreal Chikadee	Parus hudsonicus
BCC	Black-capped Chikadee	Parus atricapillus
TS	Tree Swallow	Iridoprocne bicolor
SPH	Sparrow Hawk	Falco sparverius
ST	Swainson's Thrush	Cathyrus ustulatus
R	American Robin	Turdus migratorius
HT	Hermit Thrush	Cathyrus guttatus
GCT	Gray-cheeked Thrush	Cathyrus minimus

DISCUSSION

From the data obtained in the 1978 and 1979 bird mist-netting programs there appears to be a consistent pattern emerging. Reduced recruitment of birds of the year (i.e. those hatched during the current summer) in sprayed areas is reflected by the lower juvenile/adult ratios of sprayed sites relative to unsprayed. Insectivorous bird species constitute a lower proportion of the total at sprayed sites than at the unsprayed site. However, sprayed and unsprayed sites were similar in regard to species composition. Further, recapture data for banded birds does not thus far suggest any measurable degree of mortality attributable to spraying.

There are two possible alternative mechanisms that might explain the apparent reduced production of young birds in sprayed areas. The first is that the chemical insecticide may have affected young birds toxicologically either by direct contact or by ingestion of insects etc. that contain the toxin. Unfortunately, experiments designed to elucidate whether young birds are affected in the above ways are prohibitively difficult to carry out while still maintaining the natural surroundings that the subjects would otherwise experience. There are, however, two pieces of evidence that make the toxicological mechanisms seem unlikely. First, it is difficult to understand how data would be obtained suggesting reduced production of young birds to an approximately equal degree in 1978 and 1979, when no spraying occurred in 1979. Second, our group has now spent approximately 1000 man-hours in the field and failed to observe signs of any unusual level of erratic behaviour of birds.

The second alternative explanation is based on the way in which some bird populations respond to fluctuations in insect numbers. Passerine (perching) birds, as a group, exploit a wide variety of plant and animal foods. Some specialize in feeding on insects, while others feed mainly on seeds or other plant material; still others are "jacks-of-all-trades" and can switch over to a given food source when it becomes abundant. Some species depend on plant material as adults but provide their young mainly with insect food. As a food source becomes abundant, predator birds can react in two ways: they may as individuals intensify their predation on the food source (functional response); or they may increase in number so that more birds occupy a given area (numerical response). The latter mechanism would cause bird population densities to fluctuate with the abundance of the food resource item. That some bird populations (viz. some species of wood warblers) fluctuate markedly with spruce budworm infestations has been shown by MacArthur 1958, Morris et al 1958, Mattson 1968 and, with Ovenbirds by Zach & Falls 1975.

MacArthur (1958) suggested that bird species exploiting an unpredictable resource, such as the budworm, lay a relatively high number of eggs per clutch so that in times of food abundance when full survival of the entire clutch is relatively likely, the bird population can effect a rapid numerical response and thus compete favourably

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with other bird species. This author quotes results from New Brunswick showing that Bay-breasted Warblers produced larger clutches during budworm epidemics than in non-epidemic years, and Zach & Falls (1975) provide similar evidence for the Ovenbird. Thus when the budworm infestation begins to subside, bird species showing a numerical response would be expected to decline in number and, if the epidemic collapse is sudden (as in a spray program), the decline may be dramatic. The reduction in bird numbers may also be expressed as reduced survival of the young, since the young of many species are more dependent on insect food than are the adults.

Buildup of bird population densities with growing budworm infestation followed by sudden decline as the budworm epidemic collapsed after aerial spraying has been observed in New Brunswick (MacDonald & Webb 1963, Mook 1963, and especially Sanders 1970). The effect was almost entirely due to 4 species of wood warblers. Blais & Parks (1964) observed similar buildup and decline of Evening Grosbeaks in conjunction with the budworm control measures. In each of the above situations, no evidence of direct mortality due to spraying was observed.

Budworm pupal counts and balsam fir damage assessment showed that budworm numbers were very much lower[1] at the two sprayed sites than at the control site -- not only in 1978 after spraying with Matacil, but also in 1979 when no spraying occurred there. Pre-spray surveys in 1978 indicated that budworm numbers were approximately equal among sprayed and unsprayed areas before application of Matacil. The reason for this apparent "extended protection" is unclear but it may be related to reduced dispersal of budworm moths, due to meteorological factors, in late summer, 1978.

Examination of the mist-netting results for both years suggests that the data for 4 insectivorous warbler species (Yellow-rumped Warbler, Black and White Warbler, Tennessee Warbler, and Northern Waterthrush) are largely, although not wholly, responsible for the differences in juvenile production figures between the sprayed and unsprayed sites. This, and the observation that insectivores formed a greater proportion of the total at the unsprayed site tend to support the numerical-response explanation.

If base-line bird population data were available for these sites for years prior to 1978, the question of which mechanism is the important one would almost certainly be answerable. As it is, only continued long-term studies at these and, perhaps, additional sites will eventually solve the puzzle.

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1. Relative numbers (mean $\pm$ s.d.) of budworm pupae per sampling unit near the 3 sites in Aug. 1979 were: Joe Batt's Pd. (control) = 42.53 $\pm$ 26.82; Big Careless Cv. Bk. (test) = 22.83 $\pm$ 12.56; Little Careless Cv. Bk. (test) = 6.13 $\pm$ 4.89. Big Careless Cv. Bk. was right on the actual spray border; however, mean pupal counts well inside the spray block ranged from 0.53 to 6.13 per sampling unit.

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TERRESTRIAL ARTHROPODS

MATERIALS AND METHODS

Sampling Techniques:

The 1978 monitoring program centred chiefly on flying insects. Studies of non-target terrestrial arthropod (insects, spiders, etc.) populations in 1979 were intended to deal mainly with resident (i.e. relatively immobile), plant-dwelling species.

At each sampling site, branches or whole plants were excised and immediately inserted into large polythene bags, which were then sealed and stored in coolers. Every effort was made not to disturb any of the arthropods during the "bagging" procedure; preliminary observations showed that with practice, very few or none of the fauna on the vegetation were lost between excision and enclosure in the bag. The samples were sent to St. John's where they were fumigated with ethyl acetate; the vegetation was then removed from the bags and a thorough search was made to recover all arthropods. Identification was made to the family level.

All leaves from every vegetation sample were removed, desiccated and weighed so that the results could be expressed as "insects per dry leaf weight". The plant species sampled were: speckled alder (Alnus rugosa), trembling aspen (Populus tremuloides), blue aster (Aster), white birch (Betula papyrifera), pin cherry (Prunus pennsylvanica), balsam fir (Abies balsamea), fireweed (Epilobium angustifolium), goldenrod (Solidago), sheep laurel (Kalmia angustifolia), pearly everlasting (Anaphalis margaritacea), black spruce (Picea mariana), yarrow (Achillea millefolium).

In addition to the foliage collections, pitfall trapping was carried out at one control and one test site in mature fir-spruce forest. The pitfall traps consisted of 40-ounce juice tins with one end removed. They were placed upright in the ground so that the rim of the open end lay just below the mossy surface of the forest floor. There were 40 traps installed along transects at each site. Pitfall traps are designed primarily to intercept spiders, beetles, mites, and other arthropods which disperse over the surface of the forest floor.

Sampling Sites and Schedule:

Seven sites were used in the survey: 3 were unsprayed (control), 3 were sprayed with Matacil in 1978, and 1 was sprayed with B.t. in 1979. Of these, one control and one Matacil site were in mature forest, while the others were in regeneration forest areas.

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A list of the sites, the forest types and spray history of each are given in Table 1 and the locations are shown in Figure 1.

The field team attempted to visit each site twice per week from 23 May to 15 August, 1979.

Calculations:

All of the counts for each arthropod family x plant x site x day combination have been entered into a permanent computer file. For each family, the mean number per dry leaf weight was computed for each plant species at each site over the whole season. The means were compared for statistically significant differences between sites using a one-way analysis of variance.

The Shannon-Weaver index (-H') was computed to serve as a measure of faunal diversity.

RESULTS AND DISCUSSION

1. Matacil

The terrestrial arthropod data could be displayed as 1,725 tables, each giving the catch statistics at all sites over the summer for a particular arthropod family on a particular plant. Obviously, these cannot be presented in this report due to limitations of space. Accordingly, the data was sequentially summarized as follows. First, we selected all plant x family combinations in which the total number of arthropod specimens recovered at all sites over the entire summer was 20 or more: these numbered 184. For each of these, we examined the analysis of variance looking for differences between average catches at the various sites. Each of the 184 cases was classed according to whether statistically significant differences among sites existed and as to whether any differences among sites showed a trend suggesting lower catches at sprayed sites than at control sites (for classes see Table 5). Finally, those families for which such trends were noted on more than one plant were listed. Table 6 gives this latter group of cases and shows, for each of these 7 arthropod "families" the classification for all of the plants where sufficient data was available.

From Table 6 it is evident that there are no consistent trends between sprayed and unsprayed sites for any of these "families". A possible exception is the family Entomobryiidae (Collembola: springtails). Lower numbers of this group were observed in sprayed areas in the soil arthropod study, as well. However, since only 2 sites were used for pitfall trapping, the result given in Table 6 could be due to differences in the nature of the sites themselves.

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TABLE 5: Trend classification for plant x family combinations, terrestrial arthropod survey (see text for explanation).

1. Site means significantly different ($P < .05$); sprayed sites all lower than control sites.

2. Site means different ($P < .10$); most sprayed sites lower than most control sites.

3. Site means not significantly different but sprayed sites lower than control sites.

4. Site means significantly different but no trends, sprayed sites relative to control sites.

5. Site means not significantly different, no trends.

R. Site means for control sites lower than for sprayed sites.

TABLE 6 : List of terrestrial arthropod "families" that showed trends (see Table 6) for more than one plant type.

Family	Remarks
Cicadellidae	Br.(4) Al(3) As(5) Ch(5) K(5) FW(2)
Formicidae	PF(1) Br(2) Al(2) As(5) Ch(5)
Entomobryiidae	PF(1)
All Hymenoptera	Br(4) Al(3) As(5) Ch(5) K(5) FW(2)
All Homoptera	Br(R) Al(R) As(5) Ch(5) K(4) G(1) FW(2) PE(5)
Hemiptera/Homoptera	Br(R) Al(R) Ch(5) K(4) FW(2) PF(5) G(1) PE(5) Y(R)
Total arthropods	Br(5) Al(R) As(5) Ch(R) K(4) FW(3) PF(5) BF(5) S(5) PE(5) G(1) Y(5) A(3)

Abbreviations:

Br: birch
Al: alder
As: aspen
Ch: cherry
K: kalmia
FW: fireweed
PF: pitfall traps
BF: balsam fir
S: spruce
PE: pearly everlasting
G: goldenrod
Y: yarrow
A: aster

All of the computer output for the terrestrial arthropod study may be viewed at Dept. of Consumer Affairs & Environment, Elizabeth Towers, St. John's.

2. B.t.

The catches of arthropods at the site sprayed in 1979 with B.t. were low, as compared to the control-site catches.

However, these differences existed as well before spraying was carried out. In no case was the mean post-spray catch lower than the prespray level. It is thus evident that site differences were responsible for the lower numbers of specimens captured at the B.t. site, and that there was no detectable impact of B.t. on the terrestrial arthropod fauna under examination.

SOIL-DWELLING ARTHROPODS

MATERIALS AND METHODS

The aim of the soil arthropod study in 1979 was to identify any relatively long-term effects of the 1978 Matacil spray on the soil fauna. Accordingly, soil samples were taken from 3 control sites and 3 sites sprayed in 1978. One of the control sites and one of the test sites were in mature forest, while the others were in regeneration fir/spruce stands. The sites are listed in Table 1 and shown in Figure 1.

The method used in the 1979 monitoring of soil arthropod populations was similar to that used in 1978. The reader is referred to DCAE report RA-79-2 for a discussion of the rationale of, and description of methods used in the soil arthropod studies.

RESULTS

The mean numbers of individuals of various arthropod groups recovered in soil samples from the six sites are shown in Table 7. The means recorded for the sprayed (Matacil) sites are, almost without exception, lower than those for the control (unsprayed) sites, both at mature forest and at regeneration sites. The Collembola (springtails) and Acari (mites) constitute the bulk of all arthropods and in all cases both groups showed the trend of lower mean catches at sprayed, relative to unsprayed, sites.

The above findings however, must be interpreted with caution. Population densities of most soil arthropods show marked small-scale unevenness in distribution. Furthermore, such densities are

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TABLE 7: Results of the soil arthropod study in mature forest and in regeneration forest sites.

Forest sites Mean number of arthropods per sample:

Order	Control sites C1	Control sites C5	Sprayed sites X1	Sprayed sites X4	Remarks[1.]
Araneida (spiders)	3.40	3.40	3.00	3.40	N.S.
Collembola (springtails)	116.70	92.00	53.10	39.60	$P < .01$
Acari (mites)	447.30	376.80	285.40	184.60	N.S.
Pseudoscorpions	2.60	7.00	3.10	3.00	N.S.
Total arthropods	574.40	482.80	350.10	239.60	$P < .10$
Soil humidity	60%	65%	71%	75%	

Regeneration sites

Order	Control site (C3)	Sprayed site (X3)	Remarks[1.]
Collembola (springtails)	59.60	13.40	N.S.
Acari (mites)	247.20	136.40	N.S.
Total arthropods	312.40	157.20	N.S.
Soil humidity	51%	63%	

[1.] Significance of analysis of variance test.

strongly influenced by even the most subtle variations in physical-chemical conditions in the soil.

Soil moisture content is apparently not responsible for the discrepancies in arthropod abundance between sprayed and unsprayed sites (Table 7). However, it may be that the levels of organic matter in the soil, (which forms the base of the decomposer food chain) or some other factor(s) were consistently different between sprayed and unsprayed sites and that these factors by themselves led to the observed differences in arthropod densities. To overcome such problems, a large number of study sites must be sampled so that inherent site variability would tend to "even out". Because of the vast numbers of soil arthropods generally recovered in such studies, quantifying population levels at more than 6 sites would require a major input of time and manpower. Nevertheless, it is suggested that a more extensive soil arthropod survey, involving more sites than we have examined here, would be a worthwhile inclusion in any future monitoring program.

WILDLIFE

Because no adverse impacts due to Matacil spraying were observed on shrew populations in 1978 and because it was considered likely that local small mammals disperse sufficiently rapidly to fill in any population "vacuum" that might exist one year after spraying, no small-mammal study was included in the 1979 monitoring program. Instead, an attempt was made to determine whether grazing animals, by ingesting large amounts of sprayed vegetation, might accumulate aminocarb or its metabolites in some of their tissues. This concern relates to human health as well as to the well-being of wildlife, since tissues of game animals taken by hunters are commonly eaten.

In mid-November 1978, approximately 5 months after the Matacil spraying, specimens of moose, snowshoe hare and ruffed grouse were killed in spray blocks #218 and #219 in the Glenwood Area. Samples of liver and muscle were collected from each type of animal and in addition, fat was taken from one moose. The tissue samples were kept frozen and sent to the Forest Pest Management Institute (Fisheries and Environment Canada) for residue analysis using gas-liquid chromatography with a nitrogen-specific detector. In addition to aminocarb (active ingredient of Matacil), analysis was carried out for two common metabolites of aminocarb.

Details of the sample locations and dates, together with the results of the analysis are given for each sample in Table 8. It is evident that neither aminocarb nor the two metabolites accumulated to significant levels in tissues of the sampled animals.

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Table 8 Analysis of Wildlife Tissue Samples from Newfoundland for Aminocarb and Its Metabolites

Sample No.	Sample Description as per Labels		Tissue Sampled	Concentration (ppm)		
	Species	Particulars		Aminocarb	MA(4-(methylamino*-3-methylphenol methyl carbamate)	AM(4-amino*-3-methylphenol methyl carbamate)
1	Snowshoe Hare	Male Adult, 19 Nov. 78 Winter Bil.	Liver	N.D.	N.D.	N.D.
2	Snowshoe Hare	Female Adult 13 Nov. 78 Memorial Univ. of Newfoundland Snare Set 1, Winter Brooks	Liver	N.D.	N.D.	N.D.
			Muscle	N.D.	N.D.	N.D.
3	Snowshoe Hare Gander Sp.	Male Adult S.W. Ridge between S.W. and N.W. Gander River	Liver	N.D.	N.D.	N.D.
			Muscle	N.D.	N.D.	N.D.
4	Snowshoe Hare	Female Juv. 13 Nov. 78, Spray Area Glenwood Hussey Pond	Liver	N.D.	N.D.	N.D.
			Muscle	N.D.	N.D.	N.D.
5	Snowshoe Hare	Adult Male 12 Nov. 78, Spray Block Between S.W. and N.W. Gander River	Liver	N.D.	N.D.	N.D.
			Muscle	N.D.	N.D.	N.D.
6	Moose	11 Nov. 78, Block 1185 1/2 mile west of main road, Careless Brook	Liver	N.D.	N.D.	N.D.
7	Moose	11 Nov. 78, Block 1804 between river and hill	Liver	N.D.	N.D.	N.D.
8	Moose	Male Calf, 11 Nov. 78, S.W. Gander River	Liver	N.D.	N.D.	N.D.
			Fat	N.D.	N.D.	N.D.
			Muscle	N.D.	N.D.	N.D.
9	Moose	Female Calf, 11 Nov. 78, Block 1176, Careless Brook Spray Block	Liver	N.D.	N.D.	N.D.
			Muscle	N.D.	N.D.	N.D.
10	Moose	Female Yearling, 11 Nov. 78, Block 1176 Careless Brook	Liver	N.D.	N.D.	N.D.
			Muscle	N.D.	N.D.	N.D.
11	Ruffed Grouse	13 Nov. 78, Collected J.D. Folinsbee, Joes Feeder Area	Liver	N.D.	N.D.	N.D.
			Muscle	N.D.	N.D.	N.D.
12	Ruffed Grouse	13 Nov. 78, Collected J.D. Folinsbee, Joes Feeder Area	Liver	N.D.	N.D.	N.D.
			Muscle	N.D.	N.D.	N.D.
13	Ruffed Grouse	13 Nov. 78, Collected J.D. Folinsbee, Joes Feeder Area	Liver	N.D.	N.D.	N.D.
			Muscle	N.D.	N.D.	N.D.

(1) Recovery Studies with Spiked Tissue Samples:

Aminocarb	94% ± 4%
M.A.	96% ± 3%
A.M.	92% ± 4%

(2) Minimum Detection Limits (sample size 5 g, final volume 2 ml.)

Aminocarb	0.01 ppm
M.A.	0.05 ppm
A.M.	0.01 ppm

*Nomenclature as per Chemagro

PERSISTENCE OF CHEMICAL SPRAY RESIDUES IN THE ENVIRONMENT

METHODS

Samples of balsam-fir needles, ground vegetation and soil-humus were taken from areas that had been sprayed one year previously with Matacil and two years previously with Matacil or fenitrothion. As a check on background levels of residues, samples were taken also from areas that were not sprayed in 1977 or 1978 (Table 2). The sampling program of 1979 differed from that of 1978 in that most of the sampling was done from regeneration stands (approximately 1.5-2.5m in height) rather than from mature forest. It is likely that the prospects of detecting any residues remaining after spraying would be greater from regeneration areas than from mature forest stands because exposure of tree foliage, ground vegetation and soil to the spray would be greater in the relatively open regeneration area.

Soil humus samples were taken from mature-forest areas, partly to examine the effect of a heavy forest canopy on soil residue levels, and partly to provide background information relating to the soil arthropod study.

Matacil^{R} was extracted from foliage and soil by extraction with ethyl acetate. The extract was acidified to form the water soluble acid salt, and organic co-extractives were removed by washing with methylene chloride. Neutralization converts the salt back to the dimethylamine form (organic soluble) which was then extracted into methylene chloride leaving the water soluble co-extractives behind. The concentrated extract was then quantified using a gas chromatograph equipped with a nitrogen-specific detector.

Repeated injections of 3 ng of Matacil standard gave scale deflections of 65.7 $\pm$ 3.3% full scale (a standard deviation of 5%).

Foliage samples spiked at the 1 µg/g and 0.5 µg/g levels gave average recoveries of 105%.

Chemical analyses were carried out by the Water Analysis Facility, Department of Chemistry, Memorial University of Newfoundland.

RESULTS AND DISCUSSION

From the data presented in Table 9 it is evident that measurable quantities of aminocarb persist on fir needles and ground vegetation, and in soil one year after spraying with Matacil. The results of analyses of fir needles from Pinchgut Lake indicate that very little, if any, aminocarb remained there 2 years following the spray. It should be noted that, due to the nature of the analytical method,

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TABLE 9 : Results of residue analysis of vegetation samples

Spray History	Site	Forest Type	Residue Levels (ppm)[1]: Fir Needles	Grd. Vegetation	Soil
No spray	A1	R	0.001	N.D.	N.D.
	A2	R	N.D.	N.D.	N.D.
	A3	MF	N.D.	-	N.D.
Matacil, 1978:	W1	MF	-	-	0.003
	W3	MF	-	-	0.002
	W2	R	0.037	pending	0.007
	W4	R	0.035	0.013	0.011
	G2	MF	-	0.011	0.007
	G4	MF	-	0.018	0.002
	G1	R	0.023	0.051	0.003
	G3	R	0.017	0.054	0.001
	M1 (pond sediment: <.001, <.001, N.D.)				
Matacil, 1977	P1,2,3	R	<0.001	-	-
Fenitrothion, 1977	H1,2	R	pending	-	-

[1] ppm = parts per million; N.D. = non-detectable
For locations of sites see Table 2.

values lying close to the detectable limit of 0.001 ppm[2]. (i.e. in the range 0-0.005 ppm) should be interpreted with caution, since it is possible that they result from interference (i.e. background "noise") from other substances during analysis. Such samples may in fact contain no aminocarb.

The ground vegetation residue levels were more widely dispersed in value among the sampling sites than were those for fir needles. The explanation for the greater variability seems to lie in the forest type of the site from which the samples were taken. At Glenwood (G-series) the aminocarb levels for G2 and G4 (mature forest) approximate each other, and the levels for G1 and G3 (regeneration) are nearly equal despite the fact that G1 and G2 were very near to each other spatially, as were the pair G3 and G4. Ground vegetation in the more open, regeneration areas generally is very much exposed to the descending spray swath during aerial insecticide application. Ground vegetation in mature forest stands, however, is to a great extent protected by the overlying forest canopy. Although much of the formulation is washed down onto the underlying vegetation by rain, much of the active ingredient has by that time decomposed, resulting in generally lower values on lower vegetation levels. Lower residue levels might therefore be expected on ground vegetation from mature forest.

Aminocarb levels in soil were uniformly low. This may be due to the existence, in the soil, of large numbers of bacteria and other micro-organisms, some of which can break down aminocarb.

Although aminocarb was detected in water samples taken from Careless Pond after spraying in 1978, very little or no aminocarb existed in the near-shore sediments one year later.

Attempts to detect and quantify levels of several breakdown products of aminocarb in the same samples as were analyzed for the parent compound are now in progress.

PERSISTENCE OF B.T. IN THE ENVIRONMENT

Of potential concern in any aerial spray program involving viable bacterial spores is the possibility of reproduction and subsequent buildup of the bacterial agent in the environment. The soil is the most likely site for bacterial proliferation because it provides an environment that is physically and chemically favourable for bacterial growth. If B.t. spores were able to germinate, produce vegetative cells and then multiply at a significantly high rate, effects on non-target organisms might become manifest weeks or months after spraying,

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2. ppm = parts per million.

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when B.t. densities -- although inoccuous at levels encountered immediately post-spray -- reached a level capable of producing mortality.

Accordingly, soil samples from the B.t. spray block were taken pre-spray, and at 2, 9, 18 and 44 days post-spray. The samples were kept refrigerated until analysis, which was carried out by extraction in water and growth on TBA agar. Bacterial colonies growing on the agar plates were examined and counted. It was possible to differentiate between B.t. and other soil bacteria by the appearance of the colonies. Verification was done on a proportion of the colonies for each sample by phase-contrast microscopy to examine the spore crystals. Analysis of sterilized soil samples that had been "spiked" with known amounts of the spray formulation revealed that 78% of viable spores were recoverable using the above method.

The results were highly variable among soil samples. The means (+ standard deviation) for pre-spray and post-spray samples, respectively, were 350.3 $\pm$ 371.4 and 240.9 $\pm$ 294.7 spores per 0.05 g of soil.

The pre-spray data correspond to naturally occurring B.t., or perhaps other gram-positive, spore-forming strains of bacteria that are extremely close to B.t. in appearance and certain biochemical requirements. It will not be possible to differentiate between the two until a feasible technique is developed. However, the data do show that there is no great buildup of B.t. in the soil of sprayed areas.

CONCLUSIONS AND RECOMMENDATIONS

On the basis of results from medium-term (one year post-spray) monitoring of environmental impact of spraying with Matacil, there is no evidence of major disruption of terrestrial ecosystems attributable to spraying. There are, however, several points of potential concern raised in the studies. There were lower rates of production of juvenile birds in sprayed areas relative to unsprayed; however, this may be due indirectly to spraying through reduced levels of budworm that are otherwise used by the birds as food. Population densities of some soil arthropods were lower at sprayed sites than at unsprayed sites. Further monitoring is necessary to determine whether this discrepancy is due to spraying or due merely to inherent differences among the sites themselves.

Levels of aminocarb ranging from 0.011 to 0.054 ppm were detected on vegetation in sprayed areas one year after spraying, while 0.001 to 0.011 ppm were obtained from soil samples. However, no residues of aminocarb were recovered from foliage analyzed 2 years post-spray.

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The interpretation of the possible biological effects of the low levels of aminocarb remaining on foliage one year after spraying is difficult without detailed dosage-response information on all of the major groups of organisms in the forest ecosystem: clearly, the acquisition of such data is highly unlikely. However, terrestrial and soil arthropods are the most probable organisms to be affected by residues of this insecticide, and we are of the opinion that any major impact that had begun to occur within one year of spraying would be detectable using the present methods. That no residues of aminocarb nor of its metabolites were recovered from 3 common vertebrate species in sprayed areas suggests that bioaccumulation of Matacil is not a significant problem in these higher animals.

The bacterial insecticide B.t. does not appear to have any significant adverse impact on terrestrial arthropod populations, and there is no evidence of its proliferation in the soil.

As noted above, the results of environmental studies up to one year post-spray do not indicate significant negative impact on any of the biotic communities studied. From an environmental standpoint, therefore, we cannot put forward any reasonable argument against the continued use of Matacil as a short-term pest management strategy, provided that both short-term and adequate long-term environmental monitoring is carried out. Similarly, there appears to be no reason to consider the use of B.t. environmentally harmful.

If chemical insecticides are to be used again for large-scale forest protection it is imperative that the long-term studies we have initiated be continued. Increased emphasis should be placed on investigations of bird reproductive success, soil arthropod populations, and residues of aminocarb parent ingredient and breakdown products.

Environmental impact studies would be greatly enhanced by the setting aside of certain areas that are similar in forest type to those receiving spraying protection but in which spraying would not be carried out. This would allow the collection of adequate "control" data, without which the interpretation of studies in sprayed areas is difficult. For short-term monitoring, such "control" areas should be built into any current spraying program, so that test and control monitoring areas are reasonably near to each other. In addition, several such areas within the province should be established for use in long-term environmental monitoring.

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The Memorial University of Newfoundland kindly provided laboratory space and apparatus for the processing of terrestrial and soil arthropod samples.

Finally, any scientific program is dependent on those who actually carry out the collection of the data. In this regard we are indebted to the following for initiative and conscientiousness shown over the course of the summer's work. Field team: Mary Hynes (team leader), Jennifer Burry, David Morgan, Robert O'Driscoll, Carla Woodworth. Laboratory team: Heather Jewer (team leader), Jennifer Martin, Fred O'Rourke, John Pitcher, Lorna Proudfoot, Paul Smith.

Copies of the present report may be obtained on request from:

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GENERAL SUMMARY

In 1979, environmental monitoring was carried out to assess any residual effects of the 1978 spraying with Matacil against the spruce budworm, and to assess short-term impacts, on non-target organisms, of the 1979 spraying with the bacterial insecticide B.t.

1. Matacil:

Bird mist-netting surveys indicated that (a) there was a lower juvenile/adult ratio one year post-spray in sprayed areas than in unsprayed, and (b) insectivorous bird species formed a lower proportion of the total at sprayed sites than at unsprayed. However, no major differences between sprayed and unsprayed sites were recorded in regard to species composition, and recapture data for banded birds did not indicate significant spray-related mortality. The possible mechanisms leading to the above results are discussed.

No major impacts upon populations of non-target terrestrial plant-dwelling arthropods (insects, spiders etc.) were observed, but mean population densities for soil-dwelling arthropods were generally lower in sprayed areas than in unsprayed. It is not presently known whether the latter observation is due to spraying or to subtle differences among the nature of the sampling sites.

No residues of aminocarb nor of two of its metabolites were recovered from tissue samples of moose, snowshoe hare or ruffed grouse which were taken in the sprayed areas 5 months post-spray.

Aminocarb residue levels ranging from 0.017 to 0.037 ppm were detected in samples of balsam fir needles collected from sprayed areas one year after spraying occurred. Ground vegetation from the same areas contained 0.011 to 0.054 ppm and soil samples contained 0.001 to 0.011 ppm. Fir-needle samples taken 2 years following Matacil spraying did not contain detectable amounts of aminocarb.

It is concluded, on ths basis of two seasons of monitoring, that there is no convincing argument against the continued use of Matacil provided that both short-term and long-term monitoring continue.

2. B.t.

The bacterial insecticide B.t. does not appear to have any substantial short-term adverse impact on non-target terrestrial arthropod populations and there is no evidence of its proliferation in the soil.

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